Work in Progress: Increasing Interest in STEM and Improving Retention for At-Risk Students - A Two-Year Study

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(Work-in-Progress) Increasing Interest in STEM and Improving Retention for At-Risk Students: Two Year Study

Abstract

For the past two summers, California State University, Bakersfield (CSUB) has conducted a summer research program for at-risk students as part of its NSF IUSE grant activities. The program is intended to introduce students to real-world applications of STEM majors and encourage them to persist in their degree programs. Students are identified as at-risk primarily from their mathematical placement at the remedial and pre-calculus levels. While these students may be either freshmen or sophomores by university units, they are considered first year students from the perspective of their STEM majors since they are not calculus-ready. The goal of the program is to increase retention and improve persistence, particularly with respects to completing the mathematics sequence appropriate for their STEM major.

Program participants completed pre-surveys and post-surveys to determine the effect of the program on their attitudes towards STEM. Additionally, retention in the STEM major, progress in the mathematics sequence, and overall academic progress has been tracked for program participants. The survey results for both years show this program has had a positive impact on participants' attitudes towards STEM majors, STEM careers, and STEM research. The one-year retention rate of the first cohort is much higher than the baseline STEM retention rate at the start of the IUSE grant. The first cohort is also making satisfactory progress on completion of the calculus sequence for their STEM majors and their academic progress mirrors that of the overall CSUB population.

Introduction

California State University, Bakersfield (CSUB) is located in a region with low educational achievement according to U.S. Census data (US Census Bureau, 2010). The high school completion rate and the percentage of the adult population with university degrees is lower than the national average. This leads to a high number of students entering STEM programs with poor mathematical preparation, which delays their time to graduation if they begin in remedial mathematics or pre-calculus. In Fall 2016, 37% of incoming freshmen with declared STEM majors at CSUB required at least one term of mathematics remediation. Additionally, for STEM majors over the past three academic years, the passing rate in the final term of remedial mathematics is only 30%, while the passing rate in Pre-calculus I is 62%. The passing rate is defined as the grade required to move on to the next course in the mathematics sequence (C- or better at CSUB).

We identify these students as at-risk for persisting in a STEM pathway, since their poor mathematical preparation often leads to them changing majors out of STEM or leaving campus entirely. As part of the activities for its NSF IUSE grant, CSUB has conducted a summer outreach program for these at-risk first and second year students. Students from the remedial

mathematics and pre-calculus courses are specifically targeted for recruitment to the program. While these students may have accumulated enough university units to be considered sophomores, they are still considered first-year students within their STEM major since they are not yet calculus-ready. The goal of the program is to increase retention and improve persistence, particularly with respects to completing the mathematics sequence appropriate for their STEM major.

The focus areas for the summer outreach program are roughly grouped as "Science" (Chemistry, Biochemistry, Biology, Geology), "Engineering" (Engineering, Computer Science), and "Mathematics". In (Lam, Danforth, & Hughes, 2016), the Summer 2015 one-week summer program for at-risk students in Chemistry, Engineering, and Mathematics was described and the results of the surveys were discussed. All constituents for that program suggested a longer program would be more beneficial. In response to that feedback, the program was extended to a two-week program in Summer 2016.

Three focus areas were offered in Summer 2016: Biology, Engineering, and Mathematics. Biology was chosen as the science area for Summer 2016 instead of Chemistry due to the availability of faculty mentors. As with the one-week program, pre- and post-surveys were administered to the participants of the two-week program.

Overall, 25 students completed the one-week program during Summer 2015 and 33 completed the two-week program during Summer 2016. Five of the Summer 2016 participants were also participants during Summer 2015.

This paper details the activities for Summer 2016, the survey tools used in both summers, the results of the surveys with a comparison between cohorts, and the academic tracking data for cohorts of both summers.

Prior Work

In developing the summer program, grant personnel at CSUB looked at a wide range of literature from (Alvarado & Dodds, 2010), (Charney, et al., 2007), (Fleming, Engerman, & Williams, 2006), (Garcia-Otero & Sheybani, 2012), (Grindstaff & Richmond, 2008), (Hammond & Lalor, 2009), (National Academies of Science, 2010), and (Seymour & Hewitt, 1996). These prior works focused on improving the retention and graduation rates of STEM students, along with factors that positively affect persistence in STEM majors. In particular, the NAS Crossroads report (National Academies of Science, 2010) highlighted the need for active and collaborative learning environments in order to attract underrepresented minorities and women to STEM fields and to support their success in STEM. Further, according to (Seymour & Hewitt, 1996), persistence is more related to perceptions about STEM careers, experiences with classrooms and activities, and student confidence than it is related to student ability. This conclusion was further reinforced by (Alvarado & Dodds, 2010) and (Garcia-Otero & Sheybani, 2012), which also found that persistence was related to student perceptions of their STEM fields and student

confidence in their ability to complete a STEM major. One critical component identified by (Garcia-Otero & Sheybani, 2012) to improve perceptions and confidence is exposure to real-world applications of their major through summer activities so students can see the connection between theoretical coursework and careers in STEM. Likewise, (Alvarado & Dodds, 2010) found that exposing first year students to summer research projects improved understanding of the major, confidence in their abilities, and retention in future years.

Summer Activities

Students were recruited primarily by visits to pre-calculus sections by grant personnel. Faculty in the relevant departments were also asked to recommend the program to at-risk students they advised. The outreach center at CSUB also promoted the program through social media, along with other summer research opportunities for students.

There were four faculty mentors participating in Summer 2016: two faculty mentors focusing on Engineering, one on Biology, and one on Mathematics. The Mathematics faculty mentor led the Mathematics section of the Summer 2015 program and the other faculty mentors were new to the program.

The Biology activity focused on detecting the presence of a local fungal pathogen, Coccidioides immitis, in soil samples using a polymerase chain reaction (PCR) based approach. This fungal pathogen is widely found in the service area of CSUB and is of high interest to the local biology, chemistry, and medical communities. The project began with a lecture on the pathogen and laboratory safety training. Students spent the first week of the activity preparing soil samples and learning about DNA extraction. The second week of the activity focused on using PCR techniques to detect the presence of fungal DNA in the soil samples.

One of the Engineering activities focused on the design constraints around home construction, such as project management, budgetary constraints, structural integrity, and minimizing material waste. Students were taught the basic civil engineering principles, then had to develop a project plan for a family home that met the design specifications and described all materials, labor, and costs associated with the project.

The second Engineering activity focused on gathering and processing sensor data to make a door lock system that will unlock the door when a special knock pattern is detected. In the first week, students learned how to program the Arduino microprocessor. In the second week, they worked on a prototype for the knock detection system.

The Mathematics activity was an investigation of nonlinear dynamical systems such as those used to predict chaos in population models, financial calculations, or in weather prediction. The concepts were introduced at a very basic level, with the understanding that these students were still at the pre-calculus level.

Survey Tools

Pre-surveys and post-surveys were designed to gauge the effects on the activity on student attitude. The surveys contained a set of matched questions, as listed in Table 1. Each survey also gathered additional data. On both surveys, the 5-point Likert scale was defined as 5=strongly agree, 4=agree, 3=neutral, 2=disagree, and 1=strongly disagree, while the 3-pt Likert scale was defined as 3=increased, 2=neutral, and 1=decreased. The pre-survey was administered before the activity began and the post-survey was administered on the last day of the activity.

Table 1: Matched attitudinal questions on the pre-survey and post-survey.

Question	**Type**
Rate your agreement with the following statements:	
I am interested in the field that I am studying.	5-pt. Likert
I am interested in a career in STEM.	5-pt. Likert
I am confident that I am prepared for this program. (pre) I was prepared for this program. (post)	5-pt. Likert
I am aware of the academic knowledge required for a career in STEM.	5-pt. Likert
I understand what skills are required for a career in STEM.	5-pt. Likert
I understand what research in STEM means.	5-pt. Likert
I am interested in research in STEM.	5-pt. Likert

In addition to the matched attitudinal questions, the pre-survey had three questions about student expectations, as given in Table 2.

Table 2: Pre-survey questions related to student expectations from program.

Question	**Type**
What interested you about this summer program?	Open-ended
What do you expect to learn and experience in this summer program?	Open-ended
How do you expect this program to help your academic career at CSUB?	Open-ended

The pre-survey also gathered background information and demographic data on the participants. The background information gathered was the student ID number, current academic level, current academic major, the current GPA, the last mathematics course taken, and when was the last mathematics course taken. The demographic data was the gender and ethnicity data on the participants.

The post-survey had several additional questions beyond the matched attitudinal questions. These questions related to the participant's satisfaction with the program, feedback about the program, and self-assessed change in interest. The self-assessed change in interest questions are present since people have a tendency to circle the highest rating on a Likert scale. If a participant selects "strongly agree" on the pre-survey, there is no room for improvement on the Likert scale in the post-survey, even if the participant has had a change in interest. The additional post-survey questions are given in Table 3.

Table 3: Additional post-survey questions beyond the matched attitudinal questions.

Question	**Type**
Rate your agreement with the following statements:	
• My CSUB faculty facilitator has been supportive.	5-pt. Likert
What did you like about this activity?	Open-ended
What specific knowledge and/or experiences did you gain from this activity?	Open-ended
If anything, what would you change about this activity?	Open-ended
Rate your change of interest in the following areas:	
• The field that I am studying.	3-pt. Likert
• A career in STEM.	3-pt. Likert
• Research in STEM.	3-pt. Likert
If you indicated a decrease in interest in any of the above areas, please give a brief reason why.	Open-ended
Would you recommend this program to your friends?	3-pt. Likert
If you have additional comments, please leave them here.	Open-ended

Results and Analysis

The results of the student surveys, tracking of retention and academic progress, and student interviews are detailed in the following sections. During Summer 2015, there were 25 participants who completed the pre-survey and the entire program, but only 21 participants (84%) took the post-survey. During Summer 2016, there were 33 participants who completed the entire program, but only 31 participants (94%) completed both surveys.

Demographics of Participants

Demographic data was collected on the pre-survey, so it is only available for students who completed the pre-survey. For Summer 2016, the majors for the participants were: 44.1% Biology/Biochemistry, 38.2% Engineering, 11.8% Computer Science/Mathematics, and 5.9% Geology/Chemistry. The ethnicity demographics were: 73.5% Hispanic, 11.7% White, 8.8% Black/African American, 2.9% Asian, and 2.9% decline to state. The gender demographics were 67.7% female and 32.3% male.

Over both summers, the ethnicity demographics were 58.2% Hispanic, 16.4% White, 9.1% Black/African American,7.3% Asian, 1.8% Pacific Islander/Hawaiian, 1.8% Two or More Races, and 5.5% decline to state. The gender demographics were 54.5% female and 45.5% male. The ethnicity by gender is shown in Figure 1.

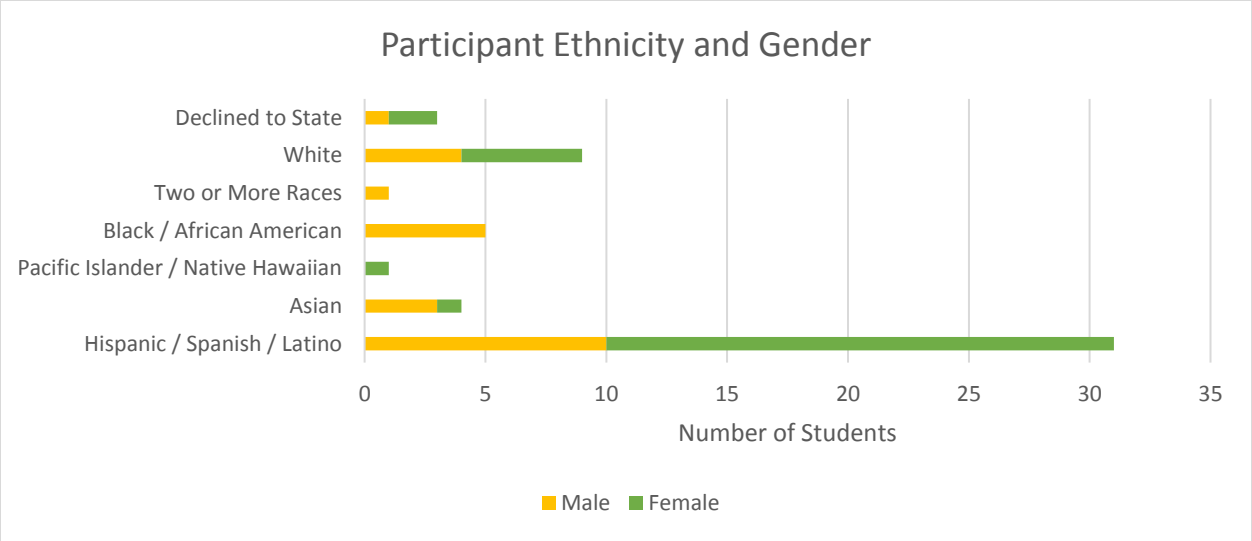

Figure 1: Participant ethnicity broken down by gender for the participants of both Summer 2015 and Summer 2016.

Trends from Surveys

For the Summer 2016 participants, there was very little significant change on the matched Likert scale questions in the pre- and post-surveys due to the student tendency to answer "Strongly Agree" on the pre-survey. The average responses and p-value for a two-tailed paired t-test is given in Table 4.

Table 4: Average response on the pre-survey and post-survey matched questions (5pt Likert scale) and associated p-value from a paired t-test.

Matched Question	**Pre Avg**	**Post Avg**	**P-Value**
I am interested in the field that I am studying.	4.77	4.90	0.103
I am interested in a career in STEM.	4.93	4.77	0.096
I am confident that I am prepared for this program. (pre) I was prepared for this program. (post)	4.27	4.47	0.297
I am aware of the academic knowledge required for a career in STEM.	4.70	4.90	0.031
I understand what skills are required for a career in STEM.	4.50	4.87	0.001
I understand what research in STEM means.	4.50	4.89	0.001
I am interested in research in STEM.	4.68	4.75	0.424

Significant increases (p-value < 0.05) were observed in the post-survey for the following: awareness of knowledge needed for STEM careers, awareness of the skills needed for a STEM careers, and understanding of research in STEM. Self-assessed change of interest questions were designed into the post-survey to account for this well-known issue of participants answering "Strongly Agree" on the pre-survey. For those self-assessed questions, 68.8% indicated that the

program increased their interest in the field they are studying, 81.3% indicated an increased interest in a career in STEM, and 87.5% indicated an increased interest in research in STEM.

In comparison to the Summer 2015 data presented in (Lam, Danforth, & Hughes, 2016), there is no difference in the post-survey self-assessed change of interest in a career in STEM and interest in research in STEM. There were more participants in Summer 2016 who indicated no change of interest in their major compared to the Summer 2015 participants. In Summer 2015, 12.5% had no change in interest in their major and 87.5% had an increase in interest. In Summer 2016, 31.3% has no change in interest in their major and 68.8% has an increased in interest. It is unclear from the post-survey open-ended questions as to why fewer students had an increase in interest in their major in Summer 2016.

When comparing the pre- and post-survey matched questions between the Summer 2015 and Summer 2016 participants, as shown in Figure 2, there is no significant difference in the interest in field of study, but there is a higher percentage of Summer 2016 participants who have a decreased interest or no change of interest in STEM careers. The reasons are unclear from the open-ended survey comments. The majority of the open-ended comments from the Summer 2016 participants who indicated no change of interest in STEM careers either said they would suggest no changes to the program or to add more time to the program, which does not provide insight into why there was no change in interest for them.

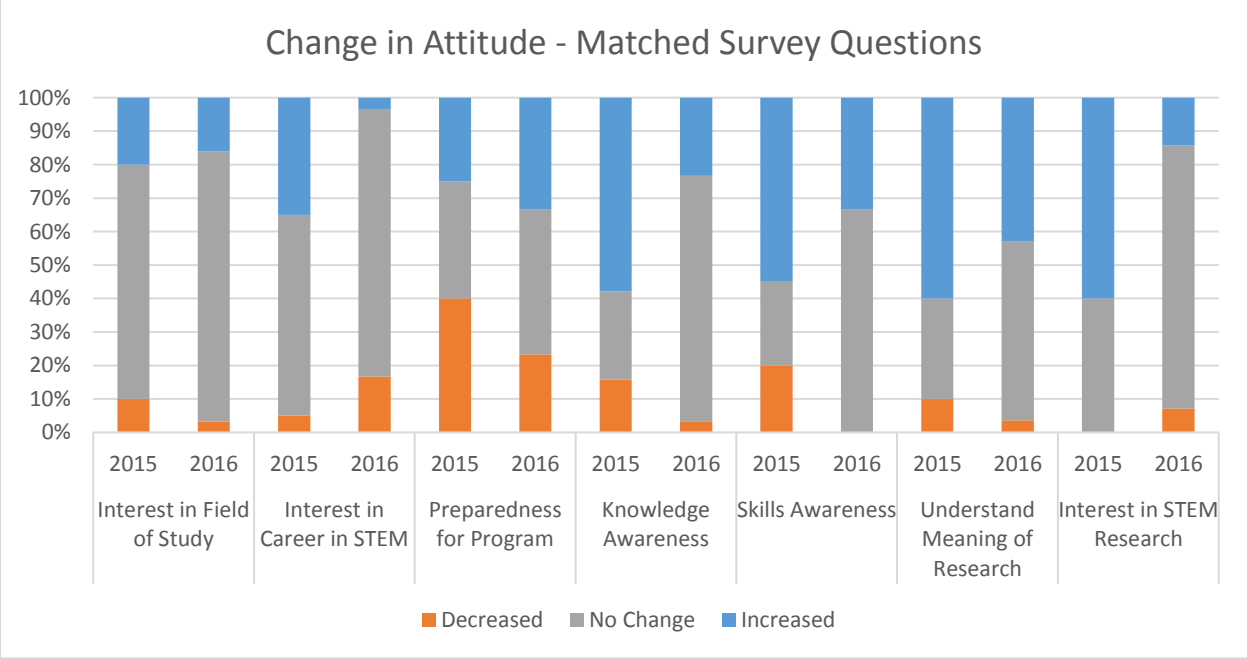

Figure 2: Comparison of change in attitude on the pre-survey and post-survey matched questions between the Summer 2015 and Summer 2016 participants.

Fewer of the Summer 2016 participants indicated a decrease in their feeling of preparedness for the program as compared to the Summer 2015 participants. Likewise, fewer of the Summer 2016 participants had a decrease in knowledge awareness, skills awareness, and understanding of the meaning of STEM research than the Summer 2015 participants. This may indicate that the students participating in Summer 2016 had a more realistic set of expectations for the program and, while they were at-risk due to their mathematical background, the program better matched their current skill-level. The extra week of program participation also gave the students more time to explore topics and gain both knowledge and skills in their respective activity areas.

When the Summer 2016 participants were asked on the post-survey to describe what they liked about the activity, the two primary areas the open-ended responses focused on were the skills and knowledge gained during the activity and the teamwork and collaborative aspects of the activity. On the open-ended question that asked participants what they would improve about the activity, the two most common responses indicated that no improvements are needed or that they would appreciate more time to work on their projects.

The responses to the open-ended question asking for additional comments were overwhelming positive with comments such as "Thank you for offering this program, I enjoyed it very much" and "Great program and experience." One of the students who participated in both years of the program noted "Overall great program / opportunity. I was able to participate last year, and I am so thankful for that. Thank you so much for the opportunity."

Insights from Student Interviews

The external evaluator for the IUSE grant visited several Summer 2016 activities and spoke with the students participating in those activities. Overall, the students valued the hands-on and interactive aspects of the activity and felt it enhanced their learning experience. Several students commented on the benefits of having more one-on-one time with their faculty mentor and receiving more individualized help as a result. Multiple students also commented that the experience helped them make sense of a topic previously covered in class or that they felt it would help them in future courses.

The external evaluator also interviewed students to see how this activity affects the participants' interest in STEM. Overall, the students indicated that it increased their interest in STEM majors and careers. One female student in particular commented that her sorority sisters avoided STEM because it is intimidating, but the summer experience has shown her that "it is actually quite interesting." Another student in her activity section followed her comment with "STEM is intimidating, but it is the most fun."

Retention and Academic Progress

The retention and mathematics progress of all of the participants, including those that did not complete the survey, has been tracked during the course of the grant. Data is collected from both the institutional research office and academic information available through the university

PeopleSoft system. The baseline retention rates in the IUSE proposal were a 1-year retention rate of 69.5% and a 2-year retention rate of 53.3%. Of the 25 students who completed the Summer 2015 program, 21 (84%) are still enrolled in a STEM program at CSUB at the end of the Fall 2016 term. Another two are still enrolled at CSUB, but have switched to non-STEM majors. The remaining two students are no longer enrolled at CSUB.

With respects to progress on the mathematics sequence, only one student from Summer 2015 is still attempting to complete the pre-calculus sequence as of Spring 2017. The other 20 students have successfully completed the pre-calculus sequence, as shown in Figure 3. Of those 20 students, 9 have completed the pre-calculus and calculus courses required for their major as of Fall 2016 and 4 of those students have moved on to the higher level mathematics courses for their majors. Overall, 15 participants are enrolled in a mathematics course appropriate for their major in Spring 2017.

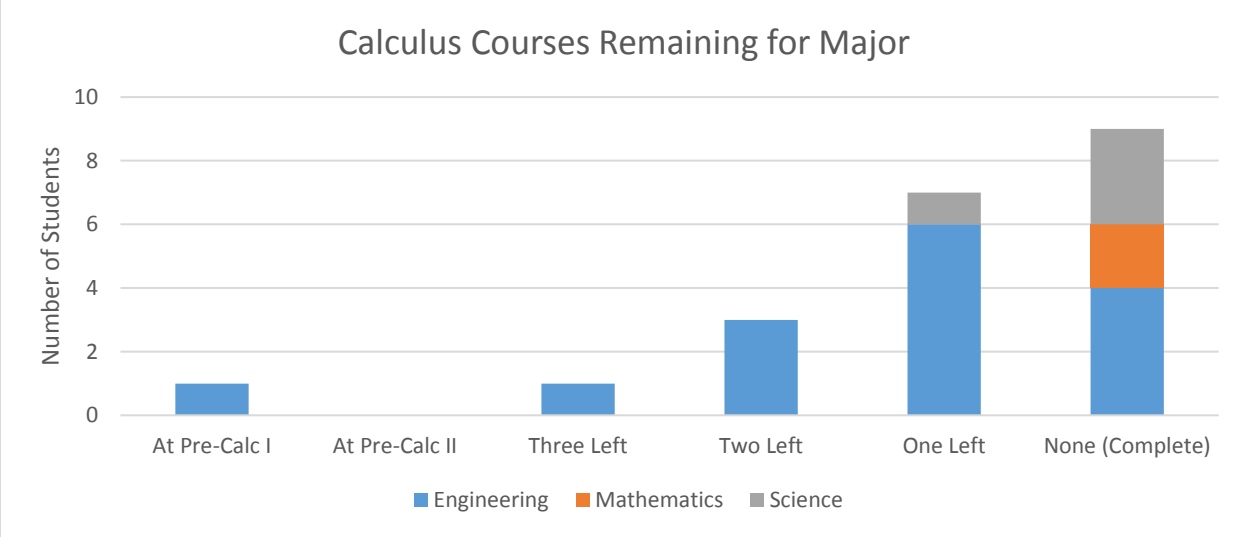

Figure 3: Number of calculus courses remaining in the major for the Summer 2015 participants, divided by major type.

The academic progress of the participants is also tracked by recording the overall campus GPA of the participants at the end of each term. The average GPA for participants closely tracks the average GPA for all students at CSUB, as shown by Figure 4. While these students are considered at-risk due to their poor mathematics preparation, their academic performance mirrors that of the overall campus population.

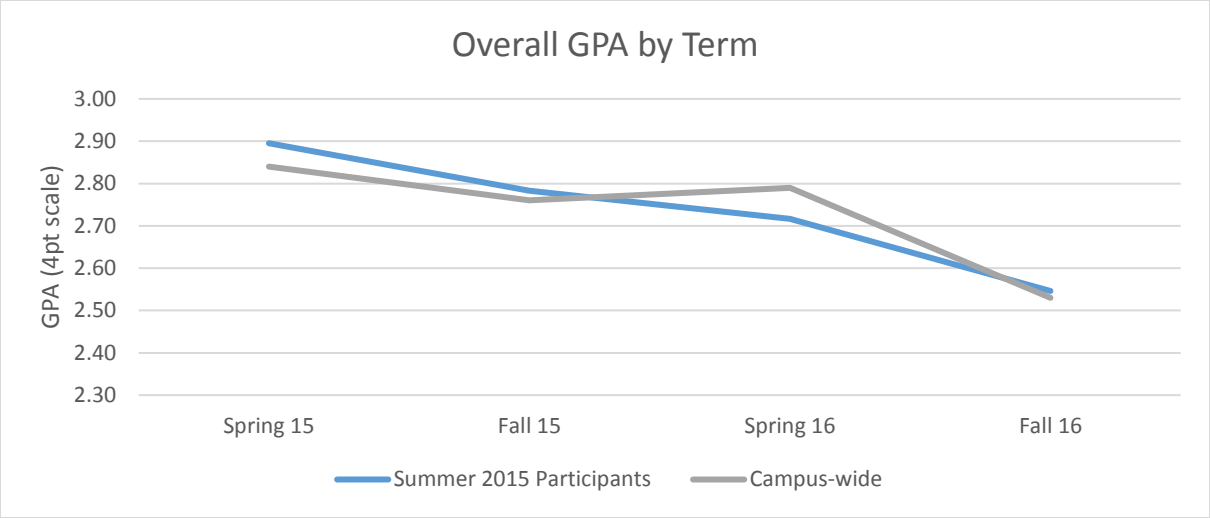

Figure 4: Term-by-term comparison of average participant GPA to average campus-wide GPA for the Summer 2015 participants.

Similar tracking is being done for the Summer 2016 participants. One engineering student withdrew from CSUB due to work commitments. The remaining students are persisting in their STEM pathways as of Fall 2016. Since only one term has been completed since their experience, it is too soon to see any trends in mathematics progress or average GPA.

Conclusion

The survey results for both years show this program has had a positive impact on student attitudes towards STEM majors, STEM careers, and STEM research. The one-year STEM retention rate of participants is much higher than the baseline retention rate at CSUB before the start of the IUSE grant.

While these students were initially identified as at-risk due to their poor mathematics preparation and placement, the majority of participants from Summer 2015 are making satisfactory progress in completing the calculus sequence required for their STEM majors, with 43% of the participants completing the required sequence in the year and a half following their activity. Additionally, the term-by-term overall GPA of the Summer 2015 participants is tracking the GPA for all students at CSUB, indicating that their academic performance is mirroring that of the overall campus population.

Future Work

While the expansion of the program to two weeks has not made any significant change on survey results, the projects attempted in Summer 2016 were more detailed than those attempted in Summer 2015 and participant feedback is overwhelmingly positive. CSUB has decided to keep the two-week format for the Summer 2017 cohort.

The personnel for the IUSE grant at CSUB will continue to track participants' current major, mathematics progression, and overall academic progress during future terms. Additional interviews and follow-up with the participants will also be explored.

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